Navigation and Thrust System for the AUVSI RoboBoat

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Objective

To design and build a system that serves as the framework for the Association for Unmanned Vehicles Systems International (AVUSI) RoboBoat competition.

Introduction

Bradley University Department of Electrical and Computer Engineering has previously competed in the Association for Unmanned Vehicle Systems International RoboBoat competition. The Roboboat competition is a prestigious event that fosters innovation in autonomous system design. Numerous subsystems are necessary for a competition ready RoboBoat.

Figure 1: RoboBoat Logo

Background

The task of designing the boat for competition has proven a task that is seldom completed within the time span of the senior capstone project timeline. To make the task of building a competition RoboBoat more feasible, the Navigation and Thrust System was developed. This system will function as the basis for any future attempts at designing a competition RoboBoat. This system will deliver the means of propulsion for the physical boat, as well providing location and orientation information upon request. This system will reduce the requirements of a competition RoboBoat design to allow future senior capstone projects the ability to compete in the RoboBoat competition.

Figure 2: Boat From Past Competition

System Block Diagram

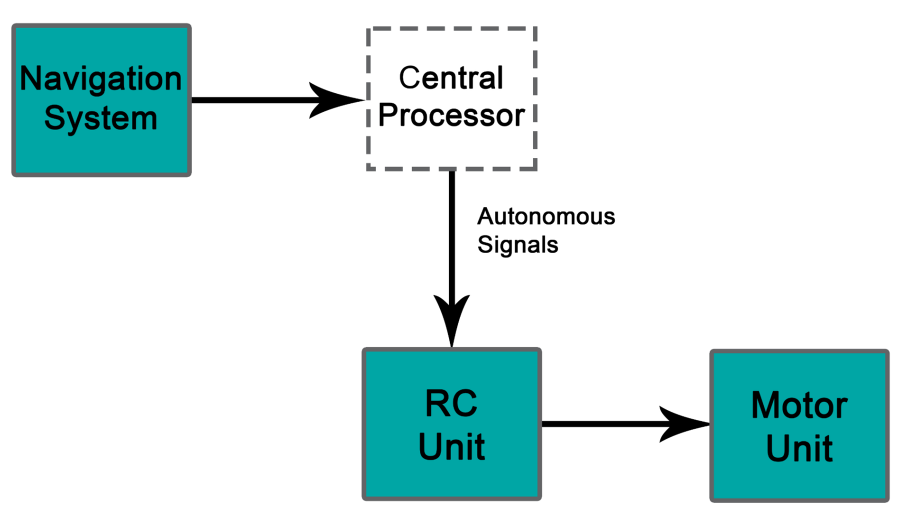


Figure 3: System Block Diagram

The Navigation and propulsion subsystems function independently as the framework, but for a competition ready RoboBoat, all components would need to be linked through a central processing unit (CPU) as shown above. The navigation subsystem transmits digital navigation data organized in data packets when requested by a central processor. The CPU would also be connected to the remote control (RC) unit, linking the framework subsystems. The RC unit is designed to receive digital serial strings of autonomous movement data from the CPU. One of the toggle switches on the RC transmitter is used as a mode selector for autonomous and RC mode. If the competition ready RoboBoat was in autonomous mode, autonomous motor commands issued by the central processor would be passed to the thrust system; otherwise, the RC user input would be sent.

Navigation System Subsystem

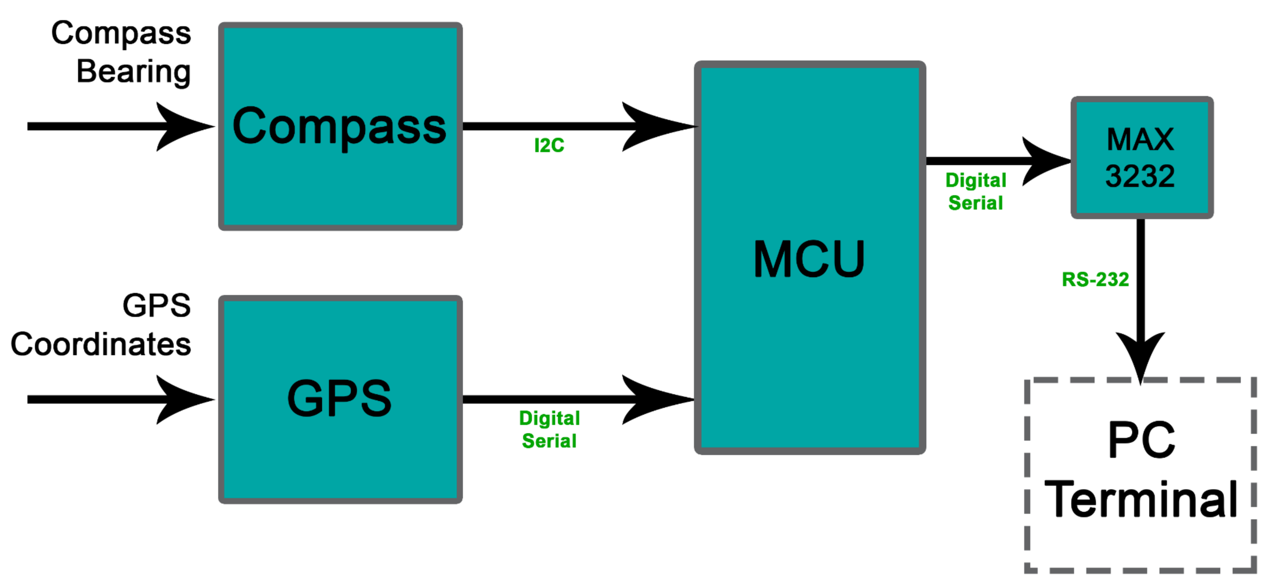


Figure 3: Navigation System Block Diagram

A navigation system is required to determine the boat's position and orientation on a body of water. An FGPMMOPA6H GPS Sensor and a CMPS10 compass sensor were integrated into the system using an Atmel Atmega1284 microcontroller to provide the system's current GPS coordinates and bearing to the CPU. A PC terminal was used for development and examples of the GPS and compass processed output data are shown below.

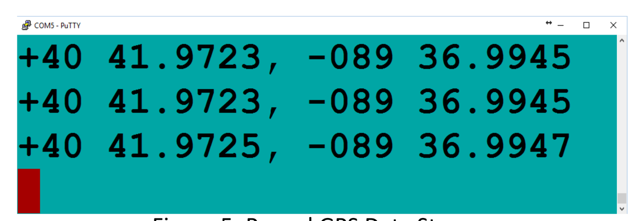


Figure 5: Parsed GPS Data Stream

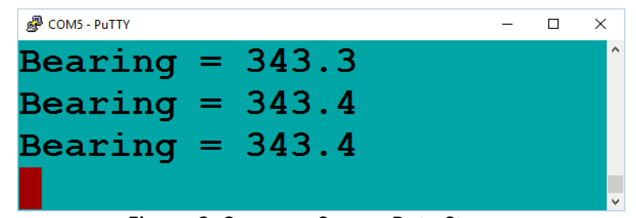


Figure 6: Compass Sensor Data Stream

Remote Control Unit

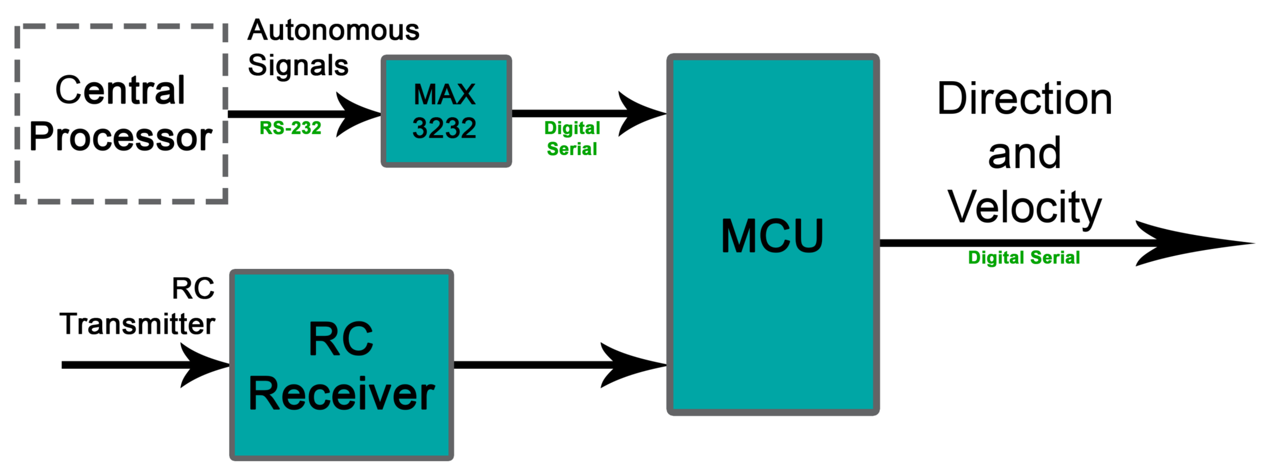
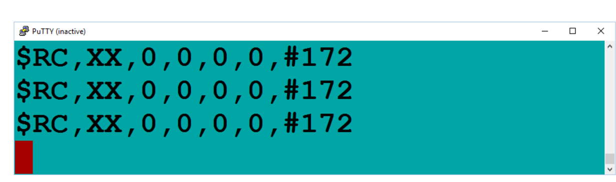
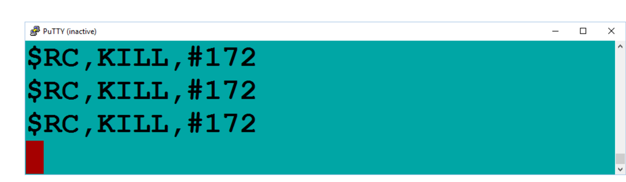


Figure 7: Remote Control Unit Block Diagram

The remote control subsystem receives signals from the RC receiver and has the functionality of receiving motor commands from the CPU. The instructions are processed and either the manual input or autonomous motor commands are sent to the motor controller according to the current mode of operation.





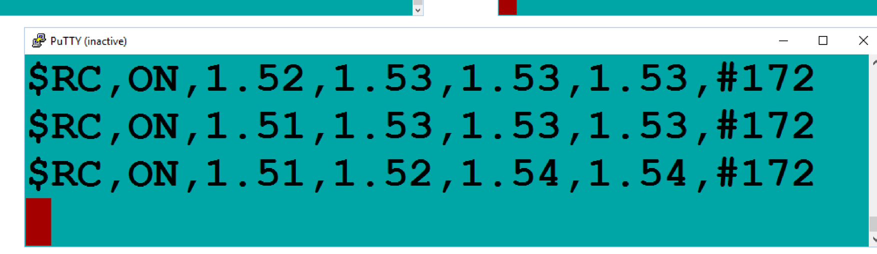


Figure 8: Remote Control Data Stream

The physical toggle switch on the RC transmitter is used to determine the mode of operation of the boat, autonomous or human control. The RC transmitter also has a kill switch that sends a motor command to shutdown the motors. If the system is not in autonomous mode or propulsion shutdown, pulse-widths are decoded from the RC received and then used to determine thrust percentages to each T100 thruster.

Motor Unit Block Diagram

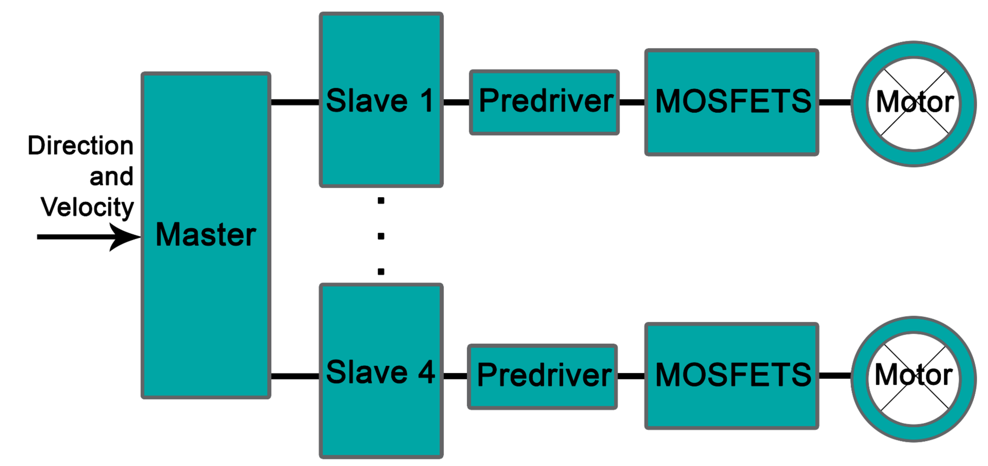


Figure 9: Remote Control Data Stream

The master microcontroller unit (MCU) is responsible for accepting the commands from the RC unit in the form of direction and velocity commands. The master MCU then interprets these signals and determines the necessary speed and thrust direction for each motor that would result in net motion that is requested. The desired speed is sent to each slave MCU to control the speed and direction of the motor. Each slave MCU is capable of transmitting and receiving data to and from the A4960 (predriver) in addition to sending a pulse width modulated (PWM) waveform that the predriver requires to determine the speed of the BLDC motor. The PWM waveform determines the speed that signals are sent out of the predriver. A metal-oxide-semiconductor field-effect transistor (MOSFET) circuit would handle the current required by each motor. As the generated PWM waveform changes duty cycle, the speed changes. An increase in positive duty cycle would result in faster commutation while decreased positive duty cycle will result in slower commutation.

Communication Structure

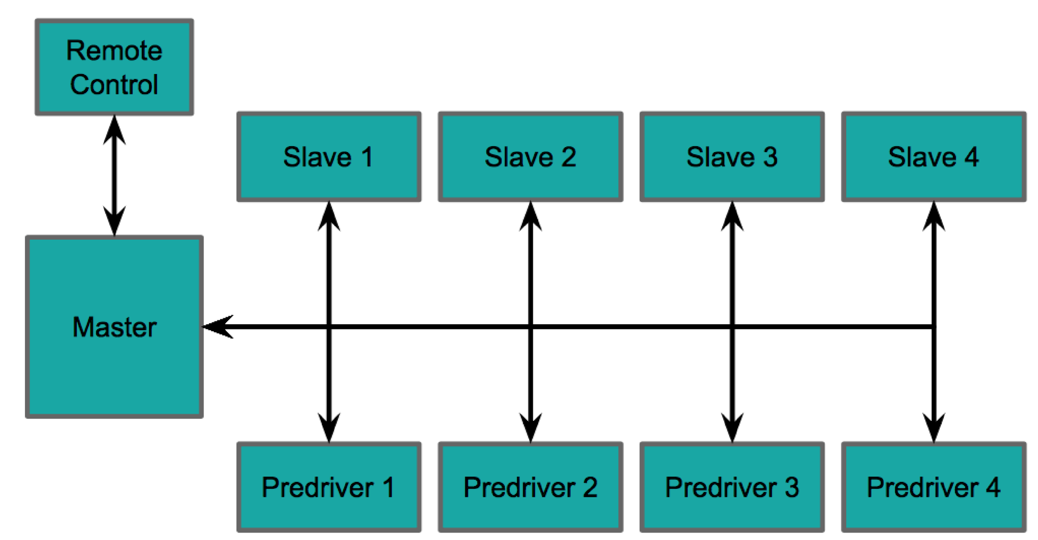


Figure 10: Parallel SPI Communication Structure

Communication capable of both transmitting and receiving data from each of the slave MCUs while also allowing for communication between the slave MCUs and their respective predrivers was necessary for the system. This task was completed through the use of the serial peripheral interface (SPI) bus. This communication method allows for communication between the master MCU, four slave MCUs, and four predrivers without error. The SPI bus allows for bidirectional simultaneous communication through the use of four unidirectional pins. See Fig. 11 for reference of the pins and their purpose. This allows information from the predrivers and slave MCUs to be recovered by the master MCU allowing for increased controllability and potential for error or failure correction.

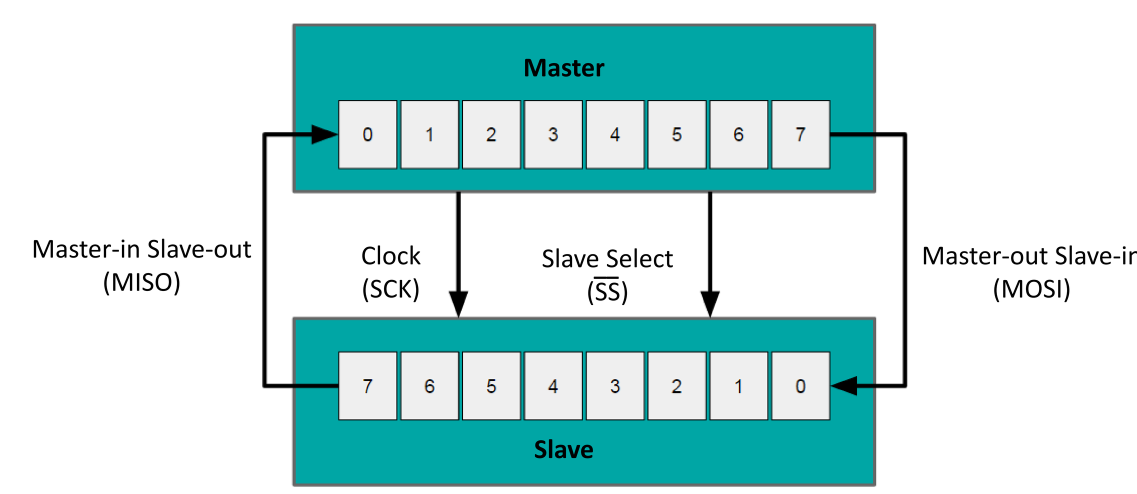


Figure 11: SPI Communication

Power Transistors

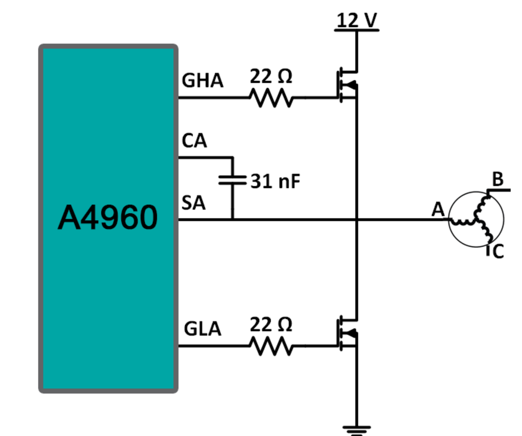


Figure 12: Designed Circuit

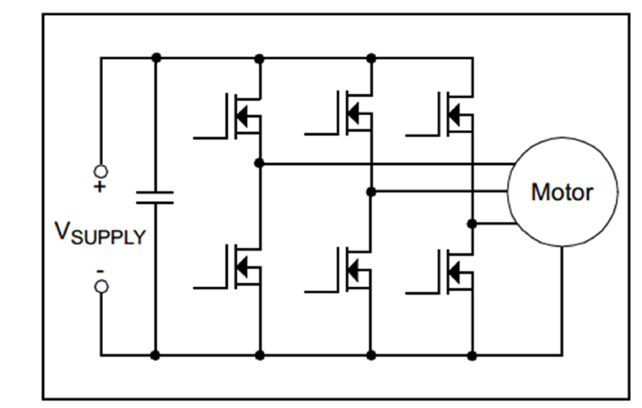


Figure 13: Triple Half H-Bridge Power Transistor Circuit

A driver is a device capable of generating signals to a BLDC motor as well as handling the necessary currents. The T100 thrusters require more current than what a driver would be able to provide, thus a predriver and power transistor circuit is necessary for operation. Using this system configuration resulted in the design of a MOSFET circuit working in tandem with the predriver that allows for higher current to be provided for the T100 thrusters.

The MOSFET circuit was created using three half H-Bridge circuits seen in Fig. 13. The signals generated by the predriver control the path of current flow. Current flows through the motor coils using three pairs of MOSFETs. Each pair has one MOSFET connected between the battery and motor (high side) and another connected between the motor and ground (low side).

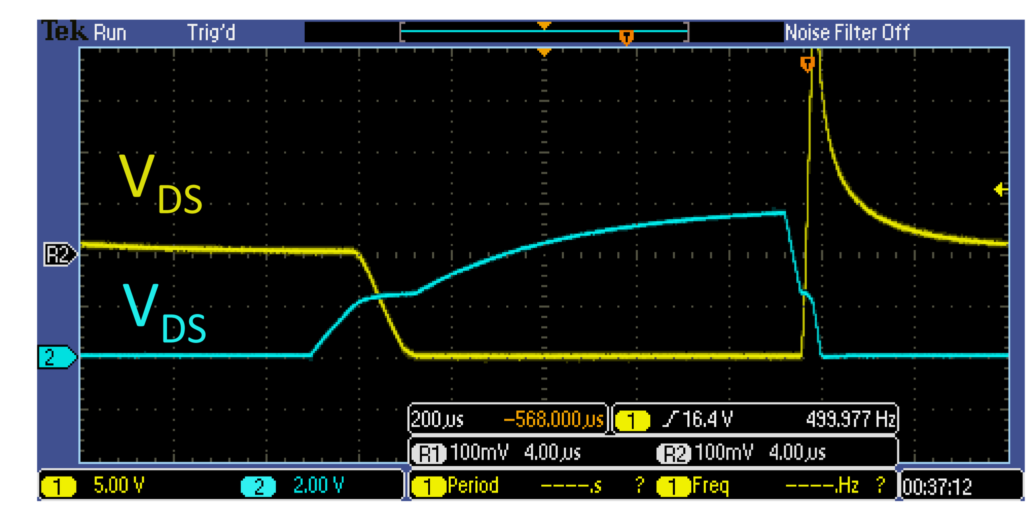


Figure 14: Artificially Slowed MOSFET Turn On Time

In order to ensure that the system operates safely, the predriver has deadtime between each state of operation to ensure the only current path operational. The power transistor circuit had to be designed to ensure the MOSFETs are capable of switching within the allotted deadtime. Figure 14 was used to determine the amount of charge necessary to activate the MOSFET.

The signals generated by the predriver are designed to control N-Channel MOSFETs. The voltage on the drain of the high side driver is the same as the voltage on the gate attempting to switch the MOSFET requiring additional circuitry to control the MOSFET. A charge pump, which provides extra voltage to the gate through a bootstrap capacitor, was used. Using an N-Channel MOSFET as a low side driver is simpler because the voltage seen at the drain is nearly ground potential because the energy has been used to move the thruster. This allows the battery voltage signal produced by the predriver to easily control the MOSFET gate.

Conclusion

The Navigation and Thrust System serves as the foundation for future senior projects working towards the AUVSI RoboBoat competition. The goals were to produce a final boat capable of navigation on the water through RC with the ability to collect data from GPS and compass units. Though the final product was never constructed, promising results were obtained for the individual subsystems.

References

[1] http://www.auvsifoundation.org/foundation/competitions/competition-central/roboboat